

## **Project name**

R&D for luminosity monitor

## **Classification (accelerator: subsystem)**

IPBI / Accelerator

## **Institution(s) and personnel**

University of Iowa, Department of Physics and Astronomy:

Yasar Onel (professor) Co-PI, E. Norbeck (professor), J.P.Merlo, A.Mestvirisvili, U.Akgun, A.S. Ayan (post-docs), F. Duru, J.Olson (grad.students), I.Schmidt (Mechanical Engineer), M.Miller (electronics engineer), E.Berry, D.Monner ( undergrad. scholars)

Fairfield University, Department of Physics:

Dave Winn (professor) Co-PI, V.Podrasky (engineer), C.Sanzeni (programmer)

Bogazici University, Department of Physics, Istanbul, Turkey:

Erhan Gülmez (professor)

Cukurova University, Department of Physics, Adana, Turkey:

Gulsen Onengut (professor)

METU, Department of Physics, Ankara, Turkey:

Ramazan Sever (professor)

INFN-Trieste and University of Trieste, Department of Physics, Italy:

Aldo Penzo (professor)

## **Contact person**

Yasar Onel

[yasar-onel@uiowa.edu](mailto:yasar-onel@uiowa.edu)

(319)335-1853

## **Project Overview**

Introduction:

The forward angle calorimeter for the LC will have large counting rates and be exposed to large radiation doses, of the order 1.0 Grad/yr. The forward detector region is shown in figure 1 and Ref [1]. The luminosity detectors are needed for a) Pair-LuMon region from 6-36 mrad for luminosity tuning. (Electron and positron are low energy  $\sim 1$  GeV) and b) Instrumented mask region from 36-117 mrad for determining absolute luminosity from Bhabhas (high energy). This concept is discussed in ref [2].

We will explore two types of detectors, the PPAC (low pressure Parallel Plate Avalanche Detector) and the SED secondary emission detector.

### **PPAC**

A calorimeter, made of PPAC, consists of heavy metal absorber, in which the shower develops, and detectors to sample the intensity of the shower.

The proposed research will develop a new type of detector that is fast (sub-nanosecond) and not subject to radiation damage. The electrical signal is generated and amplified in the detector itself. There is no need for photodetectors for PPAC.

The interior of the PPAC detector is a low pressure gas or vacuum and so must have heavy walls to withstand the atmospheric pressure. These walls will be chosen to match the material of the absorber so that they constitute part of the absorber.

A typical PPAC is two flat plates separated by 2 mm with a voltage of 750 V between them with a filling gas of 20 torr of isobutane. The charged particles passing through the gas produces ionization and the multiplication is achieved by applying a sufficiently large voltage to cause each electron to produce an avalanche. The avalanche results in current gains of  $10^4$  to  $10^5$ .

For use in a calorimeter it is better to have two heavy, grounded plates to withstand the pressure and a single, thin plate at high voltage between them. To test the performance of the detector we will make a double PPAC in which there are three thin plates, the middle one grounded. Signals are taken from the two thin plates at high voltage. A comparison of the signal from the two sides allows a measurement of the energy and time resolution of the detector.

The following is the proposed course of action for testing the performance of the double PPAC:

1. Test of PPAC at the Advanced Photon Source using 80 ps pulses of 7 GeV electrons to create electromagnetic showers.

Electromagnetic showers will be generated by allowing the halo of the beam to strike the edge of the beam pipe. The number of electrons contributing to the shower can be varied by small changes in the beam-line magnets. Since all of the electrons in the bunch are essentially simultaneous the shower will appear in the detector as if it were caused by a particle of arbitrarily high energy. This test will be done with a double PPAC, two PPACs in series so that the same shower goes through both detectors. We expect excellent energy resolution. The PPAC signal from a shower is generated by hundreds of simultaneous but independent ionization events.

2. Search for a gas to use in a PPAC that will not be subject to aging problems.

A PPAC can be constructed of materials that are extremely resistant to radiation, i.e. metals and ceramics. However under extreme radiation conditions isobutane will polymerize to form non-volatile materials. These can be removed by cleaning the detector, but it would be better if they were not formed in the first place. There are a number of promising gas mixtures. We are confident that we can find one that, if it

does not cure the problem entirely, will at least be better than isobutane.

E. Norbeck has had considerable experience with low-pressure gas detectors. Part of this experience is given in his paper on heavy gases in charged particle detectors [Nucl. Instr. and Meth. A314 (1992) 620.]. We will construct a simple PPAC with a collimated alpha source inside for testing the various gas mixtures.

### 3. Wall materials

We will do simulations to determine the material for the walls of the detector that will result in the best signal. A secondary emissive surface, as described below, may lead to better performance of a PPAC.

#### **Secondary Emission Detector**

This method collects an amplified secondary emission signal resulting from absorbed radiation sampled in a shower. The basic detector concept consists of absorber plates interspersed with secondary emission surfaces followed by sheet dynodes. The R&D will investigate: (A) materials to obtain high secondary emissive surfaces for mip's, based largely on SEM monitors used for accelerator beam diagnostics, and various dynode technologies, based on new planar PMT dynode technologies (electrochemically etched metal dynodes, others) appropriate for gains of few  $\times 1000$  per secondary electron; (B) GEANT Monte Carlo of predicted performance based on the results of (A); (C) Engineering Point Designs for assembly, vacuum integrity, signal presentation, and costs; (D) Construction & Tests (including raddam) of a single secondary emission detector package at least 5cm x 5cm square.

It is well-established that many secondary emission surfaces are radiation-hard. Typical Sb- coated SS dynodes ( $g \sim 5$ ) used in most PMT today survive 50-100 GRad of internal electron bombardment, and MgO or BeO dynodes survive higher doses, albeit at lower yield ( $g \sim 2.5-3$ ). Similar surfaces are used to monitor accelerator beams at high doses. We propose to use SEM surfaces to sample the shower caused by jets and particles in the forward calorimeters. Secondary emission for a m.i.p. typically falls to a gain  $g$  between  $g \sim 1.1-1.5$ . Conservatively, we thus anticipate that 10% of through-going mip's will create one secondary electron, and 50% of electrons with energies less than 100 keV will produce one extra secondary electron. On this basis we estimate, by scaling from scintillator or quartz fiber calorimetry, that with 2.5 cm thick sampling plates in Cu we would detect  $>10$  vacuum secondary electrons/GeV. With a gain of  $\sim 1000$ , this would be sufficient for forward calorimetry (the equivalent of  $\sim 1$  p.e./GeV, with an intrinsic pre-gain fluctuation of  $\sim 30\%$  per p.e., to translate to optical calorimetry), with excellent timing characteristics.

A default gain mechanism is to use large area planar metal dynodes with micro-machined apertures for secondary electron impingement and transport, such as metal meshes, or structures similar those used in the Hamamatsu R5900. The micromachining is a relatively low-cost electrochemical etch. The planar dynodes can be made from  $\sim 1$  mm thick metal sheets as large as 50 cm on a side. An assembly might use simple insulating supports between secondary emission cathode, dynode and anode plane. The areal size is not a restriction as in a planar PMT assembly, where the glass window thickness becomes prohibitive if the span is unsupported, whereas a metal thickness could be made sufficient

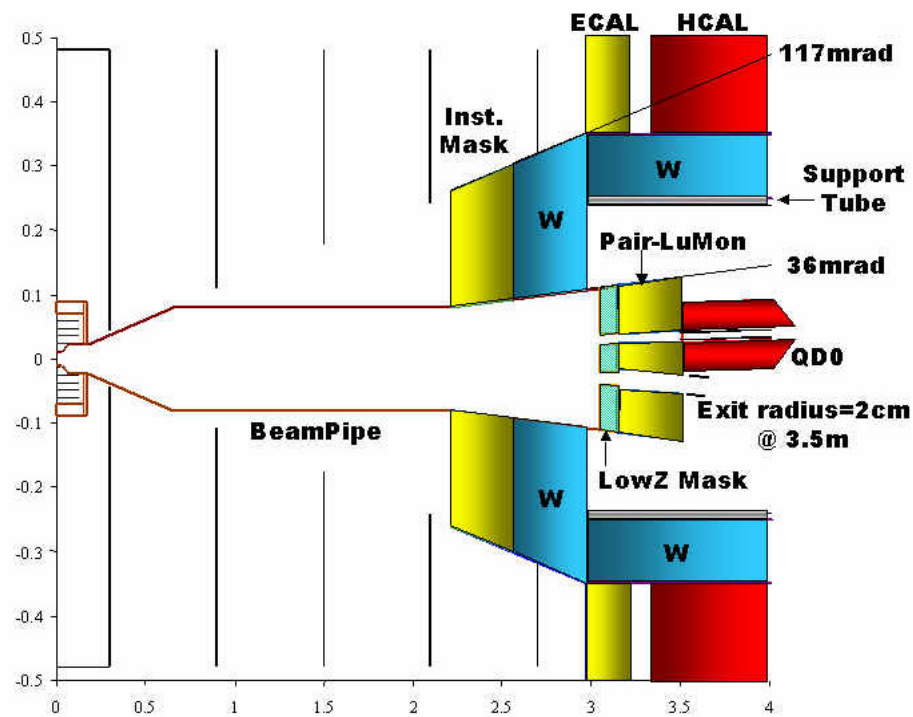
for any vacuum and be counted as part of the absorber, and the presence of internal supports of the vacuum envelope (non-glass window) are not as disruptive as in a PMT. For example, the supports might obscure as much as 10% of the SEM cathode or dynode (on a few cm areal scale), with little effect on the performance of a forward calorimeter, as the effective open detection area is not as critical as in a PMT for single photon detection. In one realization, for example, the sem cathode, mesh dynodes, and anode are all supported by simple stackable ceramic support grids, fired from a molded greensheet. The dynodes can be spaced at  $\sim 1$  mm apart, as in modern PMT. Given that a 10 stage PMT at 2 kV typically has a gain of  $10^6$ , a 5 stage gain section with  $g=1,000$  at 1 kV is reasonable. The SEM cathode, dynode stack, and anode could be less than 1 cm thick. A simple metal package could use  $\sim 5$ -15 mm thick plates on top & bottom to withstand vacuum over a 30+ cm span, with a 1 mm thick x 1 cm deep metal wall between them, with a brazed ceramic fitting on the anode side for the HV and signal. As an example, an effective 2.5 cm Cu thickness with an effective 1 cm of vacuum SEM detector would have a density  $\sim 70\%$  of Cu. A tile might be  $\sim 3.5$ -4 cm thick, with a  $\sim 30$  cm major diameter, in square or hexagonal cross-section to the beam, or even as sectors, with the anode segmented appropriately for the polar-angle sectors, and with appropriate bias for signal and HV to pass through a stacked calorimeter. With care, the dead region between tile edges could be as small as 3-4 mm, which could be ameliorated by alternating overlap in subsequent longitudinal tiles.

For the phase I R&D on this project, we propose studying the possibility of this to a sufficient level where information on performance and cost are sufficient to enable a decision to build a prototype calorimeter in subsequent proposal phases. The R&D will investigate: (A) materials to obtain high secondary emissive surfaces for mips, based largely on SEM monitors used for accelerator beam diagnostics, and various dynode technologies, based on new planar PMT dynode technologies (electrochemically etched metal dynodes, others) appropriate for gains of few x 1000 per secondary electron; (B) GEANT Monte Carlo of predicted performance based on the results of (A), for response of incident electrons between  $\sim 10$  MeV – 250 GeV, including secondary electron optics; (C) Engineering Point Designs for assembly, vacuum integrity, signal presentation, and costs; (D) Construction & Tests (including raddam) of a single secondary emission detector package at least 5cm x 5cm square.

We will be collaborating with the group of Dr. M. Woods/SLAC and Eric Torrence/U. Oregon on this research.

Institution	Item	FY04	FY05	FY06
Iowa	Partial support for post-doc	\$16.0k	\$8.0k	-
Iowa	Partial support for grad. student	-	-	-
Fairfield	Support for undergrad. student	-	-	-
Iowa	Detector/Raddam testing/operations	-	\$5.0k	-
Fairfield	Detector/Raddam testing/operations	-	\$5.0k	-
Fairfield	Secondary Emission Detector Package	-	-	\$10.0k
Iowa	Engineering	-	-	\$6.0k
Iowa	Travel	\$3.0k	\$3.0k	\$2.0k
Fairfield	Travel	\$3.0k	\$3.0k	\$2.0k
	Indirect cost @ 25.5%	\$ 5.61k	\$ 6.12k	\$ 5.1k
	Grand total	\$27.61k	\$30.12k	\$25.1k

Figure 1:

**NLC Forward Masking, Calorimetry & Tracking 2003-04-01**

## References

- [1] [http://www-sldnt.slac.stanford.edu/nlc/configs/2003/plots/Forward\\_Tracking\\_NLC\\_LD.jpg](http://www-sldnt.slac.stanford.edu/nlc/configs/2003/plots/Forward_Tracking_NLC_LD.jpg)
- [2] <http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/white.pdf>
- [3] Gas Detectors for High Energy EM and Hadronic Showers  
[http://pion.physics.uiowa.edu/HEP-web/RnD/docs/RnD\\_LC\\_PPAC.ppt](http://pion.physics.uiowa.edu/HEP-web/RnD/docs/RnD_LC_PPAC.ppt)

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